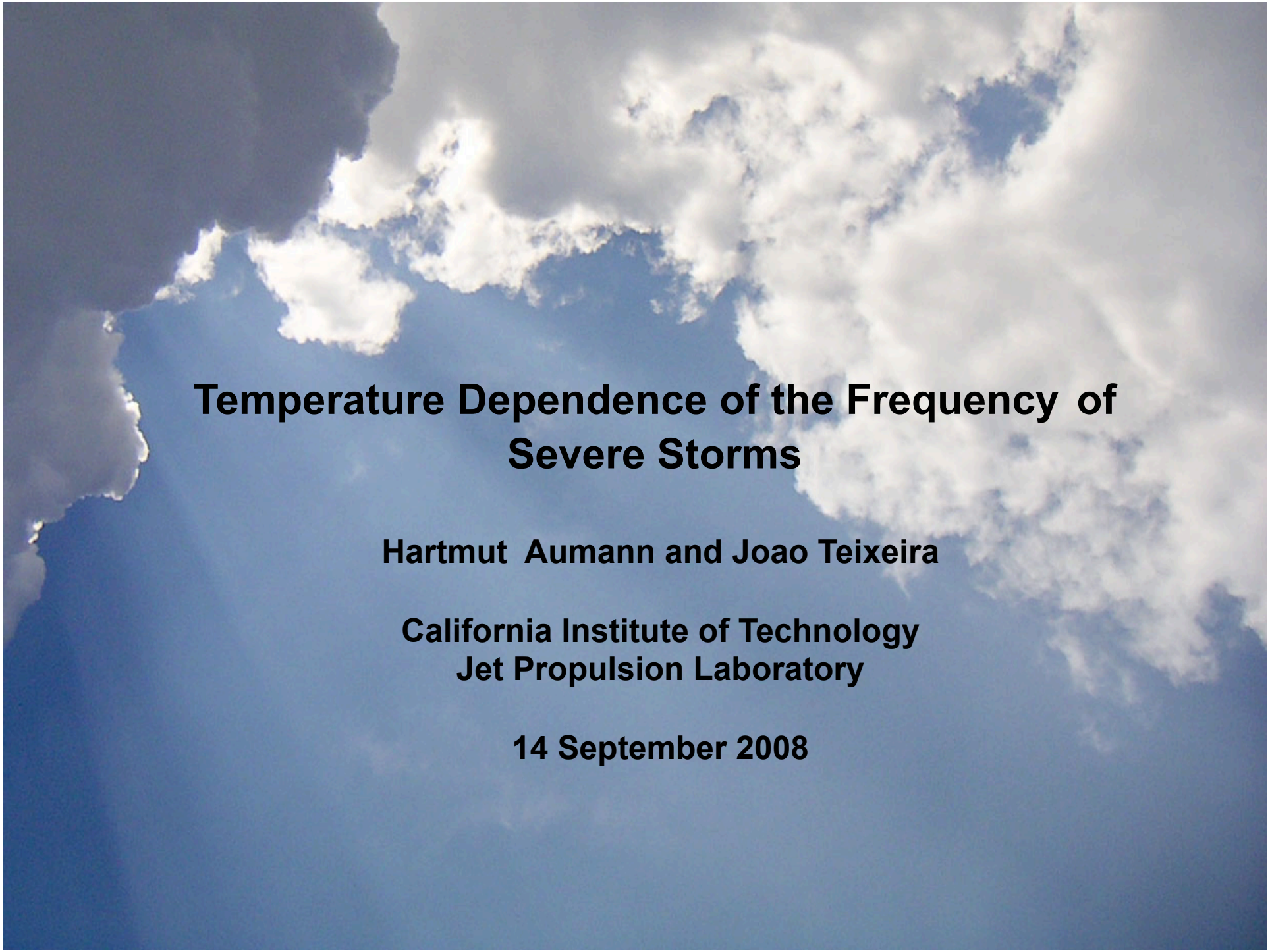

Temperature Dependence of the Frequency of Severe Storms

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California Institute of Technology
Jet Propulsion Laboratory

14 September 2008

We use 5 years of AIRS data to determine how Nature responds to global warming with a change in convective activity, i.e.

we derive a sensitivity equation which relates the frequency of deep convective clouds to the mean zonal surface temperature.

This results in a scaling equation, which can be used to test climate models.

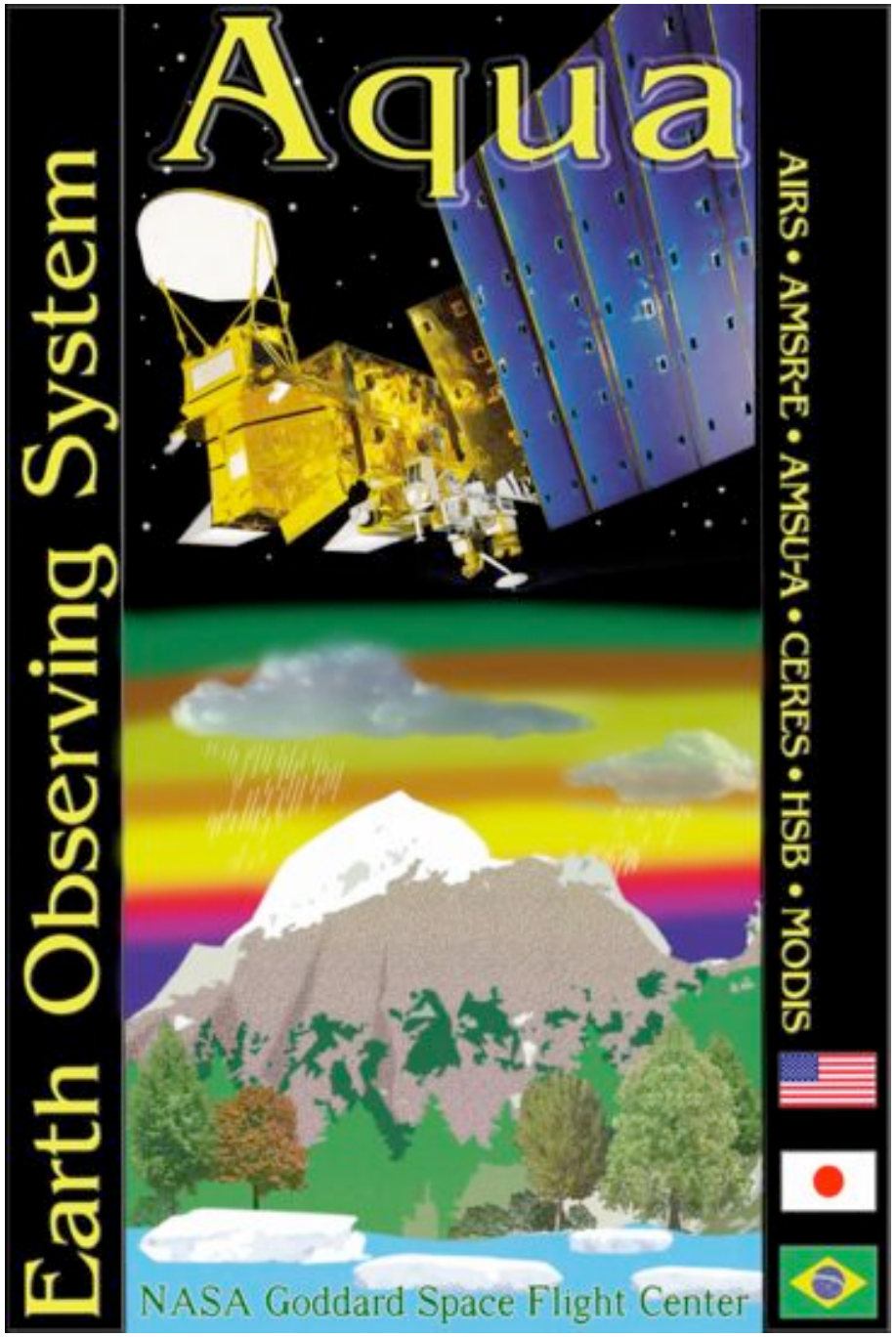
GRL doi:10.1029/2008GL034562
GRL doi:10.1029/2006GL029191

Outline

- Source of of the data
- Deep Convective Clouds (DCC)
- Frequency of DCC and mean surface temperature
- DCC and Global Warming
- Precipitation and DCC
- Conclusion

AIRS/AMSU/HSB

Spacecraft:	**EOS Aqua**
Instruments:	**AIRS, AMSU, HSB, MODIS, CERES, AMSR-E**
Launch Date:	**May 4, 2002**
Launch Vehicle:	**Boeing Delta II Intermediate ELV**
Mission Life:	**5 years**



AIRS Project Objectives

1. **Support Weather Forecasting**
2. **Climate Research**
3. **Atmospheric Composition and Processes**

Latest Prediction: 12 year life
= year 2014

Outline

Source of of the data

→ Deep Convective Clouds (DCC)

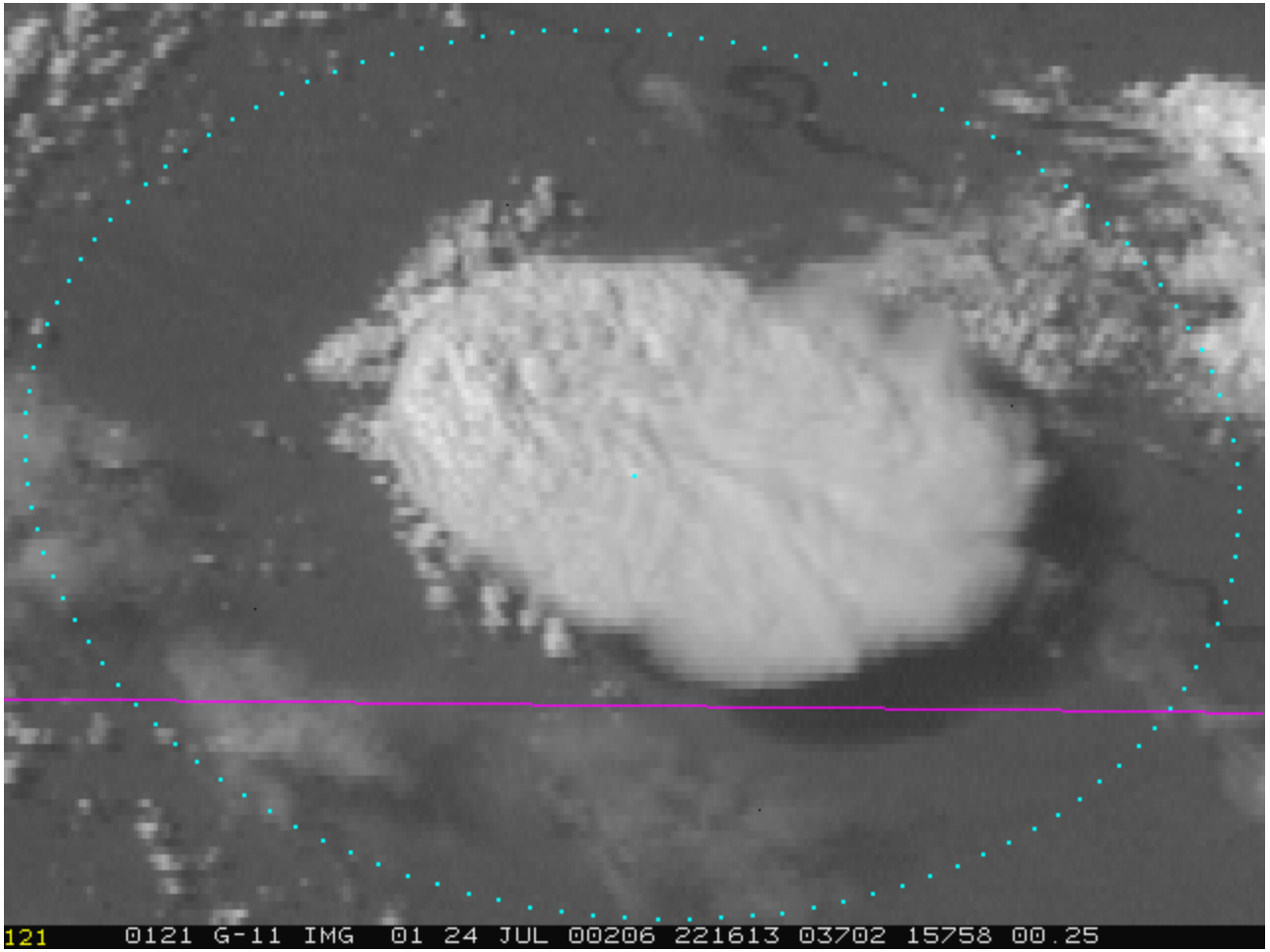
Frequency of DCC and mean surface temperature

DCC and Global Warming

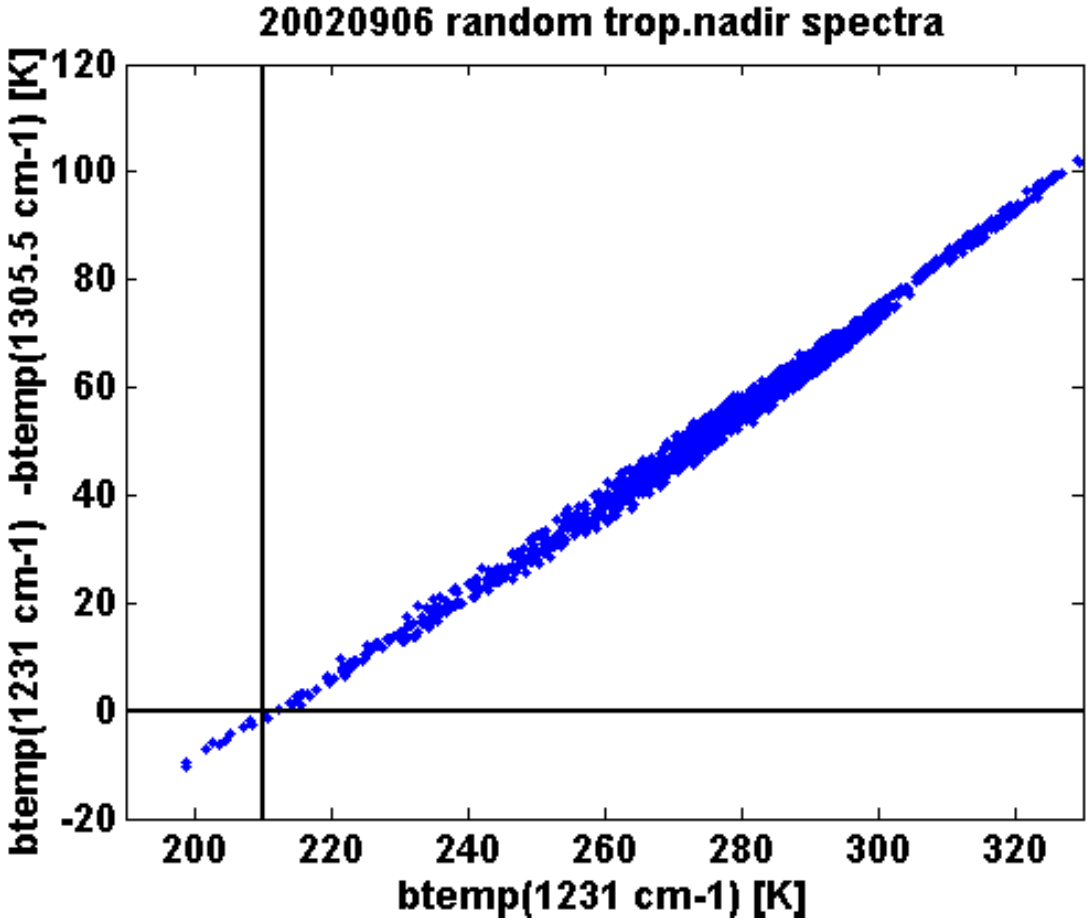
Precipitation and DCC

Conclusion

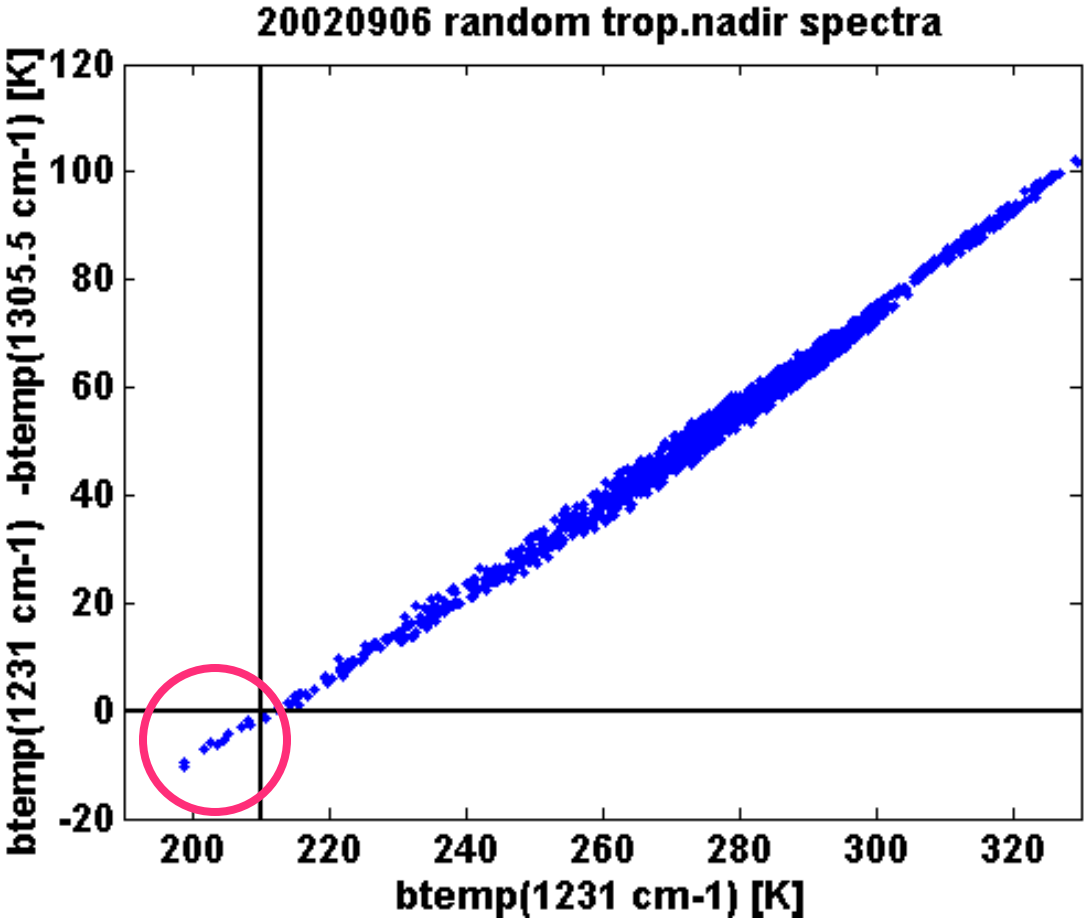
DCC were discovered using GOES data.
Reynolds (1986) and Purdom (1991) correlated
DCC with severe storms and extreme precipitation



The depth of the strong waterline at 1305.5 cm-1 vers. the brightness temperature in the 1231 cm-1 window channel

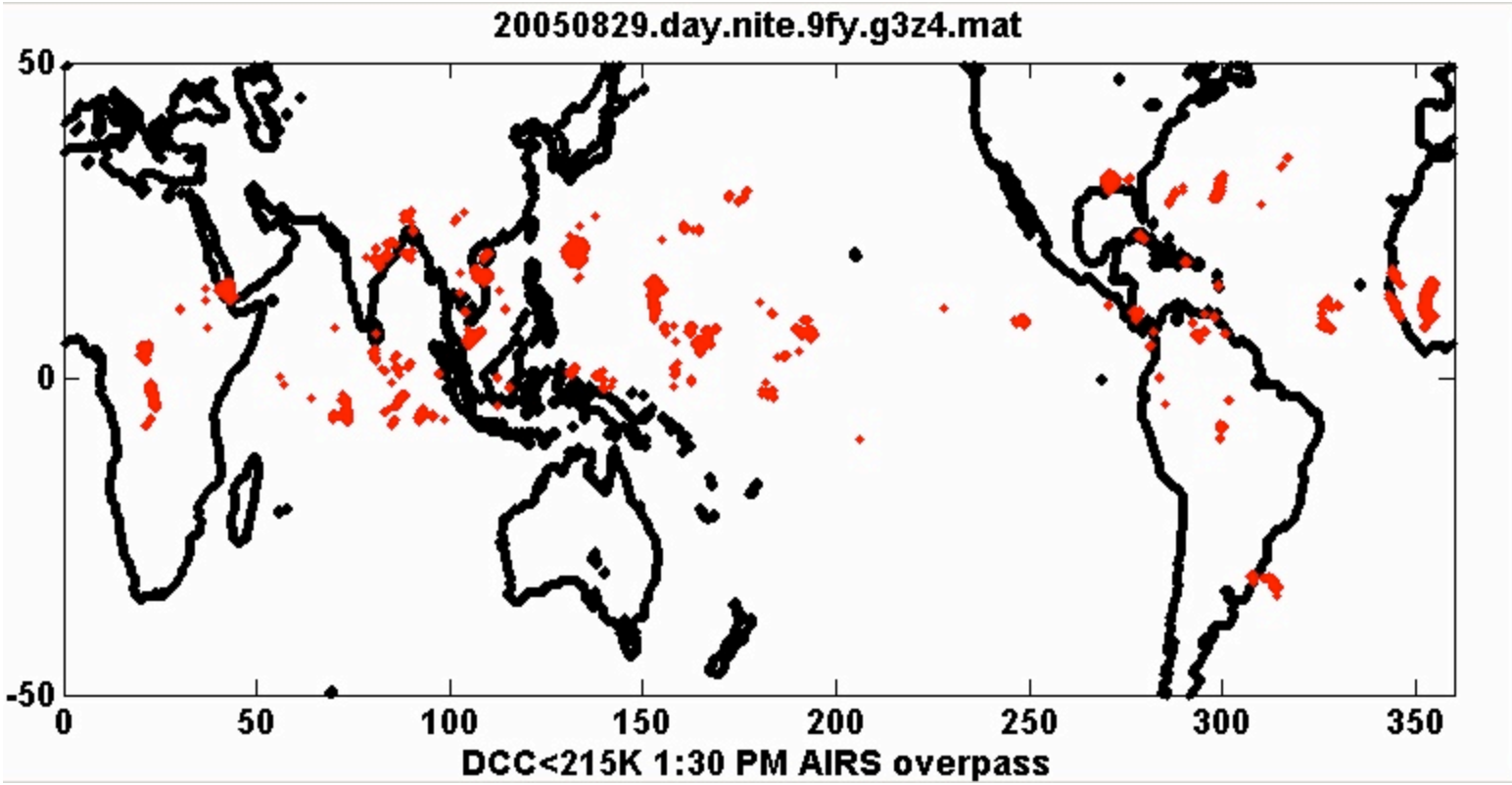


We define a DCC as any spectrum where bt1231-bt1305<0 at the tropical latitudes. This is equivalent to bt1231<210 K.



Every day AIRS identifies about 10,000 DCC, about 55% at night, 45% during the day

Most DCC are found in clusters with more than 50 DCC in a 2 x 2 degree box



DCC on 20050819 during the 1:30 PM orbits.

Outline

Source of of the data

Deep Convective Clouds (DCC)

→ Frequency of DCC and mean surface temperature

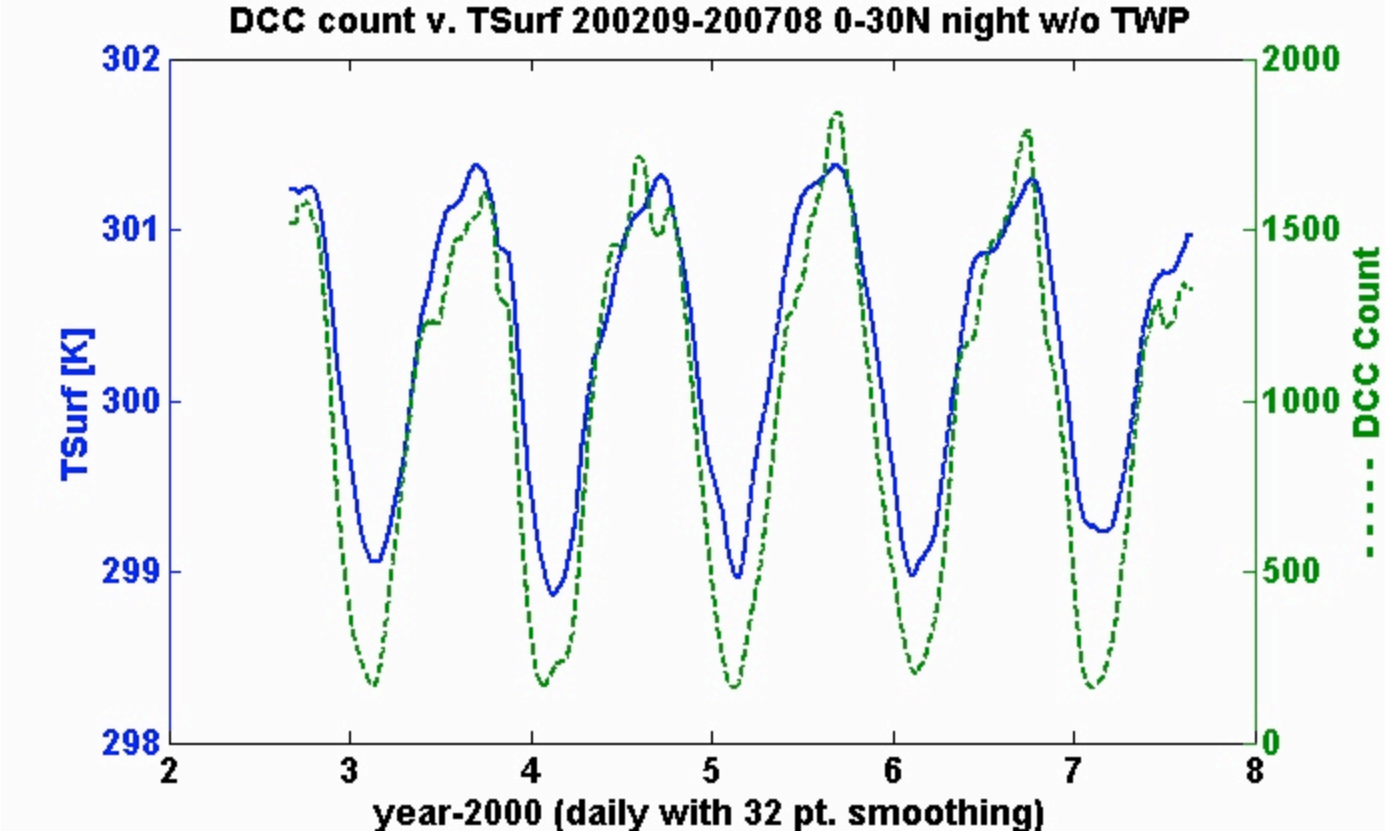
DCC and Global Warming

Precipitation and DCC

Conclusion

DCC count is highly correlated with the mean zonal SST

Zonal mean TSurf



DCC count

For night 0-30N the correlation is 0.62

Aumann et al. 2007 GRL

We use the seasonal change in the temperature of the ocean as a free large scale experiment to evaluate how Nature responds to a change in surface temperature with a change in the frequency of DCC

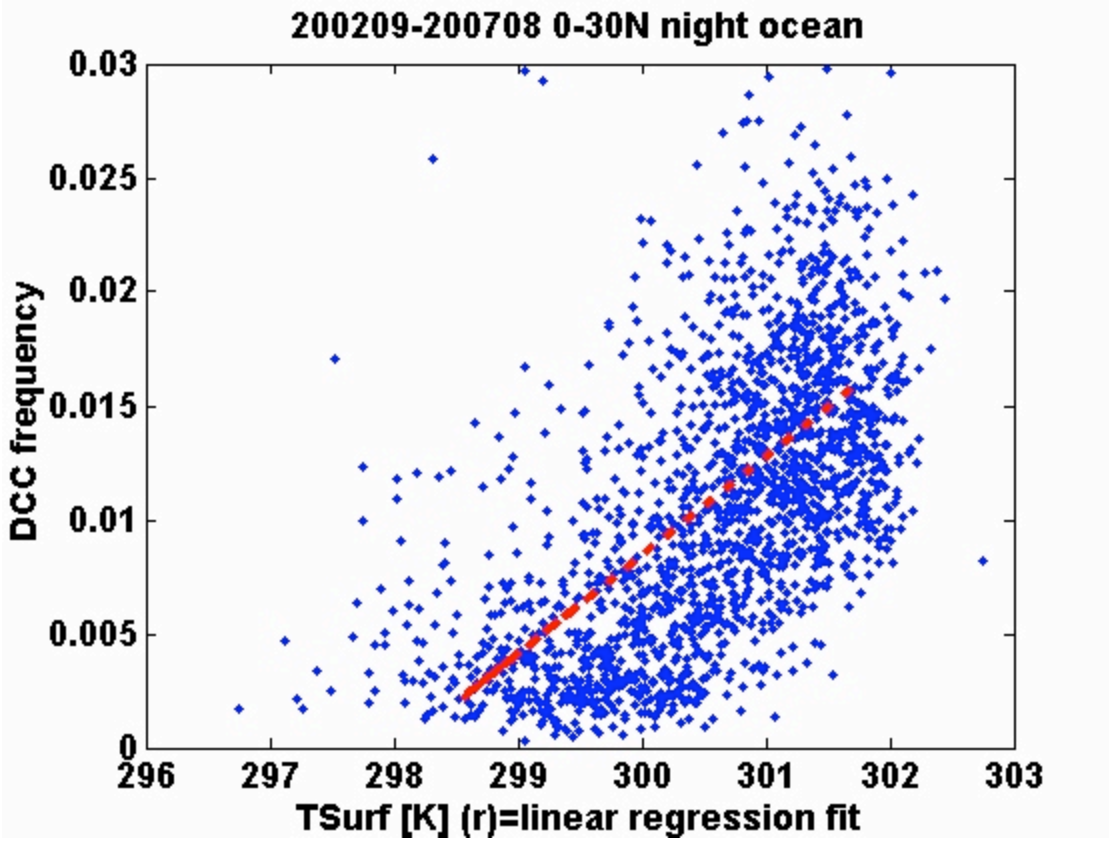
We analyze the data in terms of the DCC frequency, i.e. the DCC count divided by the number available spectra.

The DCC frequency for the tropical oceans is approximately 1% for the 1:30 pm EOS Aqua orbit.

The IASI DCC frequency (9:30 am orbit) is also about 1%.

IASI is consistent with AIRS. There is very little day/night variability in strong convection in the tropical oceans.

DCC frequency correlation with TSurf results in a DCC frequency sensitivity of 48%/K



Aumann, Ruzmaikin and Teixeira GRL doi:10.1029/2008GL034562

The DCC frequency sensitivity uncertainty was evaluated by breaking up the data into four independent groups.

	Five year mean DCC frequency	DCC frequency/ TSurf correlation	sensitivity [fraction/ K] with TWP		Five year mean DCC frequency	DCC frequency/ TSurf correlation	sensitivity [fraction/K] without TWP
0-30N day	**0.0085**	**0.611**	**0.45**		**0.0058**	**0.603**	**0.56**
night	**0.0105**	**0.622**	**0.48**		**0.0066**	**0.610**	**0.52**
0-30S day	**0.0062**	**0.661**	**0.48**		**0.0027**	**0.591**	**0.37**
night	**0.0073**	**0.678**	**0.29**		**0.0035**	**0.592**	**0.35**

DCC is a process which occurs with a frequency which is a function of the mean zonal surface temperature.

Nature responds to a increase in the surface temperature by increasing the DCC frequency by 45%/K .

Outline

Source of of the data

Deep Convective Clouds (DCC)

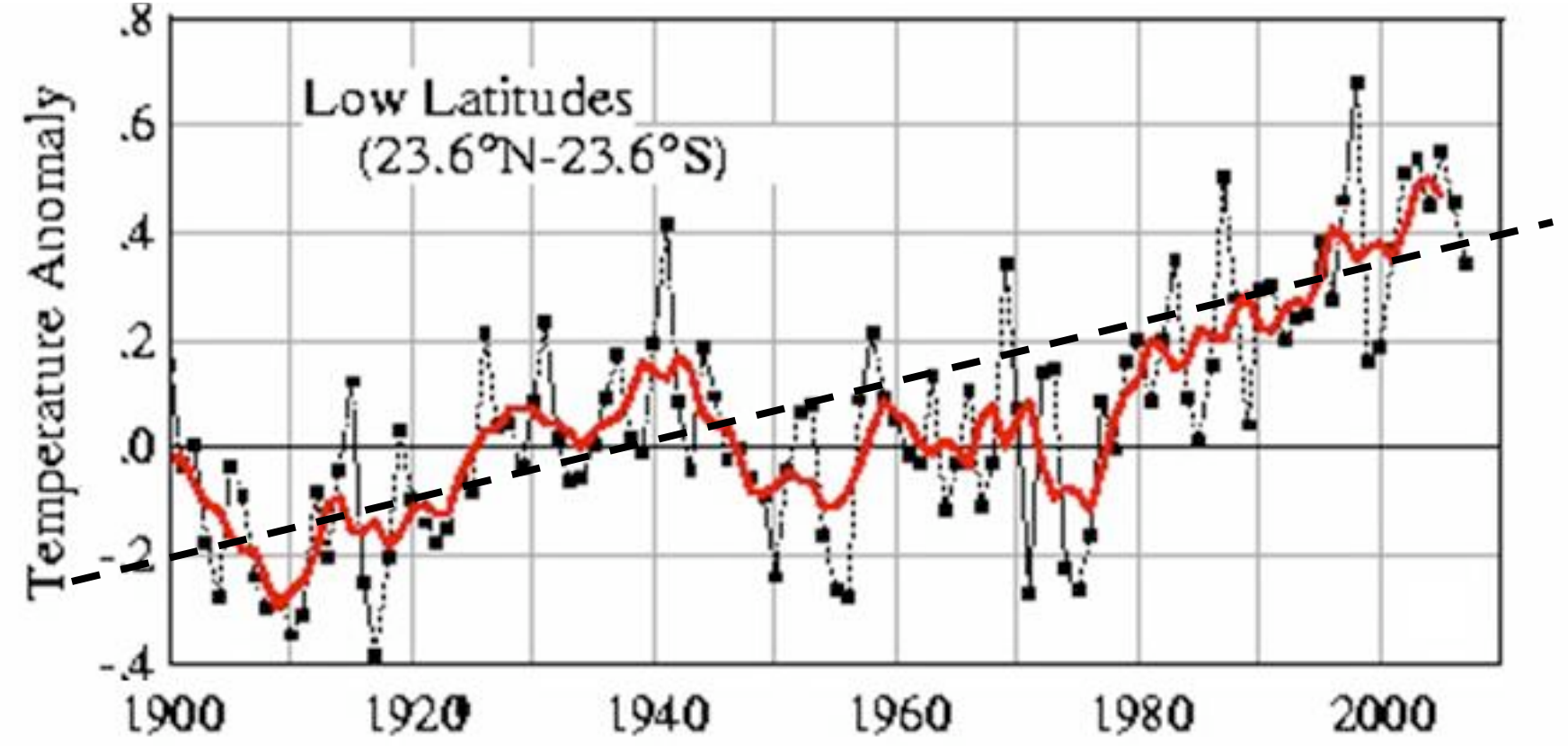
Frequency of DCC and mean surface temperature

→ DCC and Global Warming

Precipitation and DCC

Conclusion

On a 100 year scale the temperature in the tropical zone has increased at the rate of 0.13 K/decade



The black dots are the annual mean anomaly of the observations,
The red line is a five year smoothing fit.

Expected changes with global warming

The mean DCC frequency sensitivity is (+45±15) %/K

50 year trend in global warming is +0.13 K/decade

Combine the two equations to predict the increase in DCC frequency

(+45±15) %/K * 0.13K/decade = (+6±1.5) %/decade

The frequency of severe storms increased with
global warming at the rate of 6%/decade.

Outline

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AMSRE on the EOS Aqua spacecraft measure rain rate.

Mean tropical ocean rain rate: 0.12 mm/hr

The rain rate at the DCC identified by AIRS is obtained from AMSRE

DCC are correlated with the most intense rain events.

Mean Rain rate at AIRS DCC matchups with AMSRE: 3 mm/hr

DCC cover about 1% of the tropical oceans.

DCC contribute 25% to the tropical ocean mean rainfall.
(3 mm/hr * 0.01 area = 0.030 mm/hr compared to total of 0.12 mm/hr

A 6%/decade increase in the DCC frequency increases total precipitation from DCC alone from 0.030 mm/hr to 3 mm/hr * 0.01*1.06 = 0.032 mm/hr

The increase is 0.002 mm/hr per decade

0.002 mm/hr / 0.12 mm/hr mean = + 1.7%/decade.

How does this compare to the Climate Models?

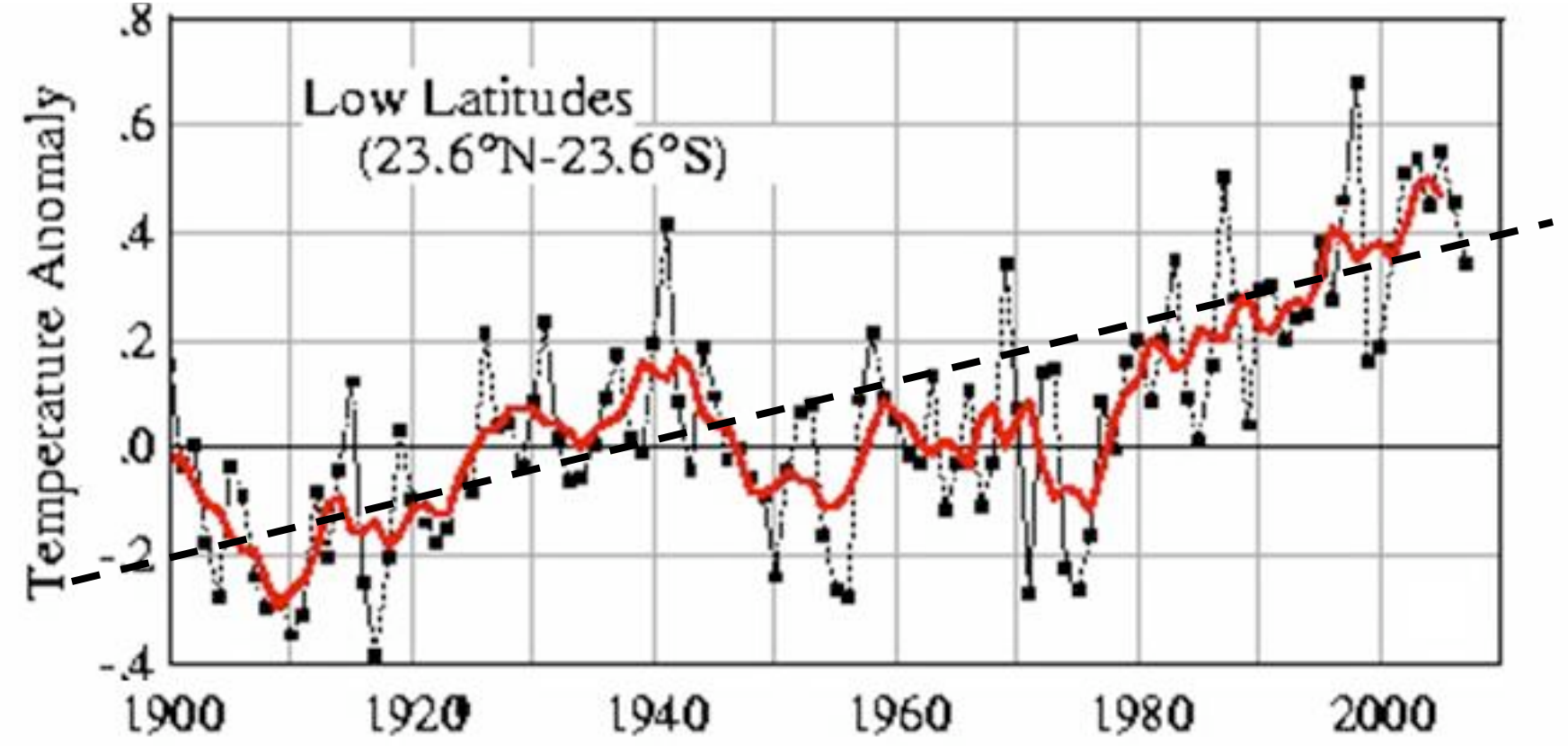
Held, I.M. and B.J. Soden (2006) "Robust Responses of the Hydrological Cycle to Global Warming",
J.Climate, v.19, 5686-5699

"... the major Climate Models predicted

... 2%/K increase in precipitation

… with global warming

On a 100 year scale the temperature in the tropical zone has increased at the rate of 0.13 K/decade



The black dots are the annual mean anomaly of the observations, the red line is a five year smoothing fit to the data.

Data downloaded from http://data.giss.nasa.gov

H. H. Aumann JPL

Held, I.M. and B.J. Soden (2006) "Robust Responses of the Hydrological Cycle to Global Warming", J.Climate, v.19, 5686-5699

"... the major Climate Models predicted

... 2%/K increase in precipitation

… with global warming

2%/K * 0.13 K/decade = 0.3%/decade increase in precipitation with global warming

The major Climate Models predicted
an increase of 0.3%/decade increase in precipitation
with global warming

DCC: +1.7%/decade increase precipitations.

The major Climate Models predicted
an increase of 0.3%/decade increase in precipitation
with global warming

DCC: +1.7%/decade increase precipitations.

SSMI data:
Wentz (2007): +1.5%/decade increase in precipitation.

The major Climate Models predicted
an increase of 0.3%/decade increase in precipitation
with global warming

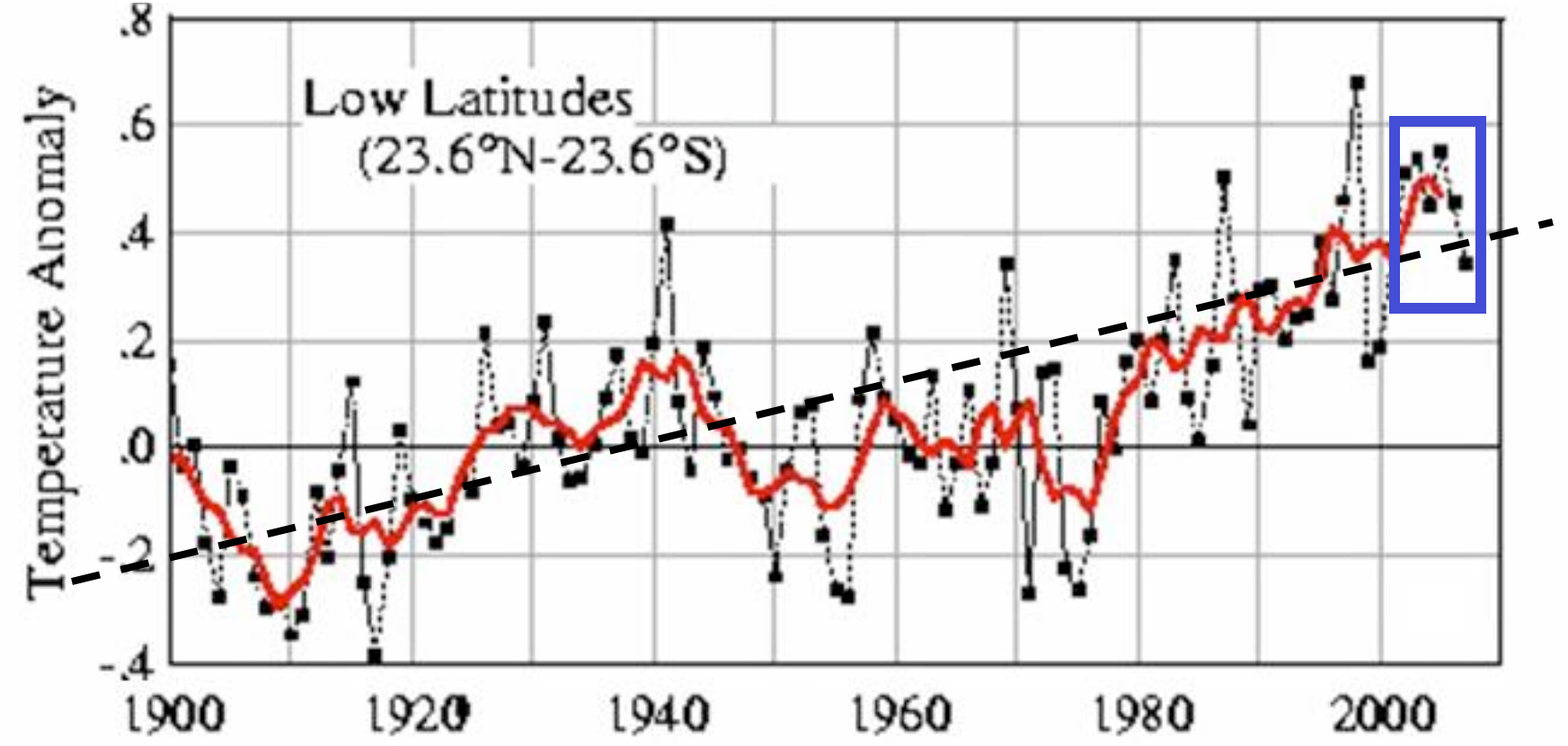
DCC: +1.7%/decade increase precipitations.

SSMI data:
Wentz (2007): +1.5%/decade increase in precipitation.

The climate models respond to global warming with a factor of five less precipitation then is derived from two independent sets of observations

Can the change in the DCC frequency or the rain rate be detected in the first 6 years of AIRS data?

The short answer is: NO



With EOS Aqua we are looking only at the last six years, where the temperature in the tropical zone decreased between 2002 and 2007.

Conclusions

Nature responds to global warming with strong increase in the convective activity.
The increase in the frequency of DCC is 45%/K.
This scaling equation can be used to test cloud resolving climate models.

The frequency of DCC and the associated severe storms increases with the current global warming at the rate of 6%/decade.

Conclusions

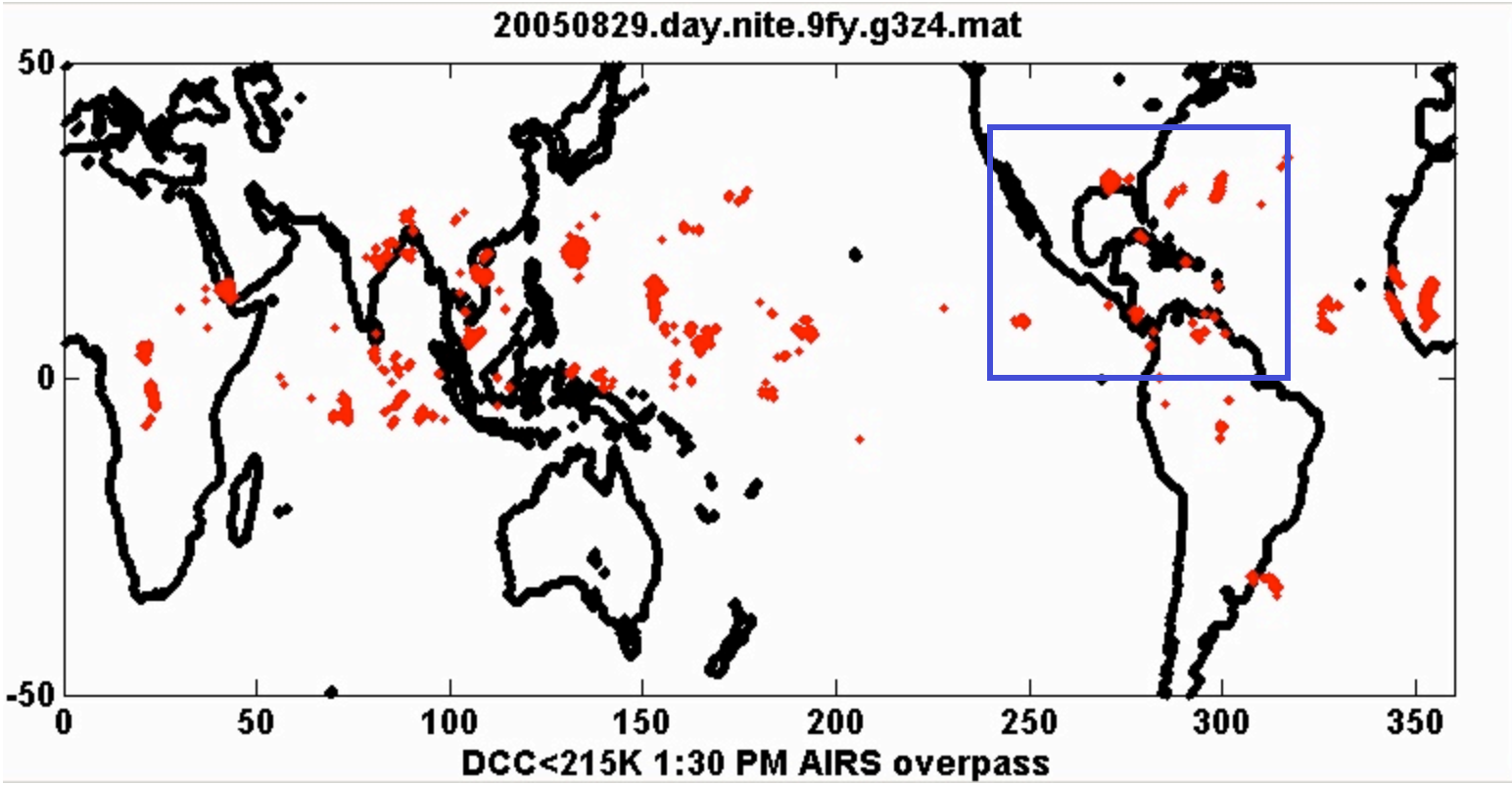
The parametrization of Climate Models needs to be tuned to more closely emulate the way Nature respond to global warming.

The increased frequency of DCC with global warming alone increases precipitation by 1.7%/decade.

State-of-art climate models respond to global warming with only a 0.3%/decade increase in precipitation

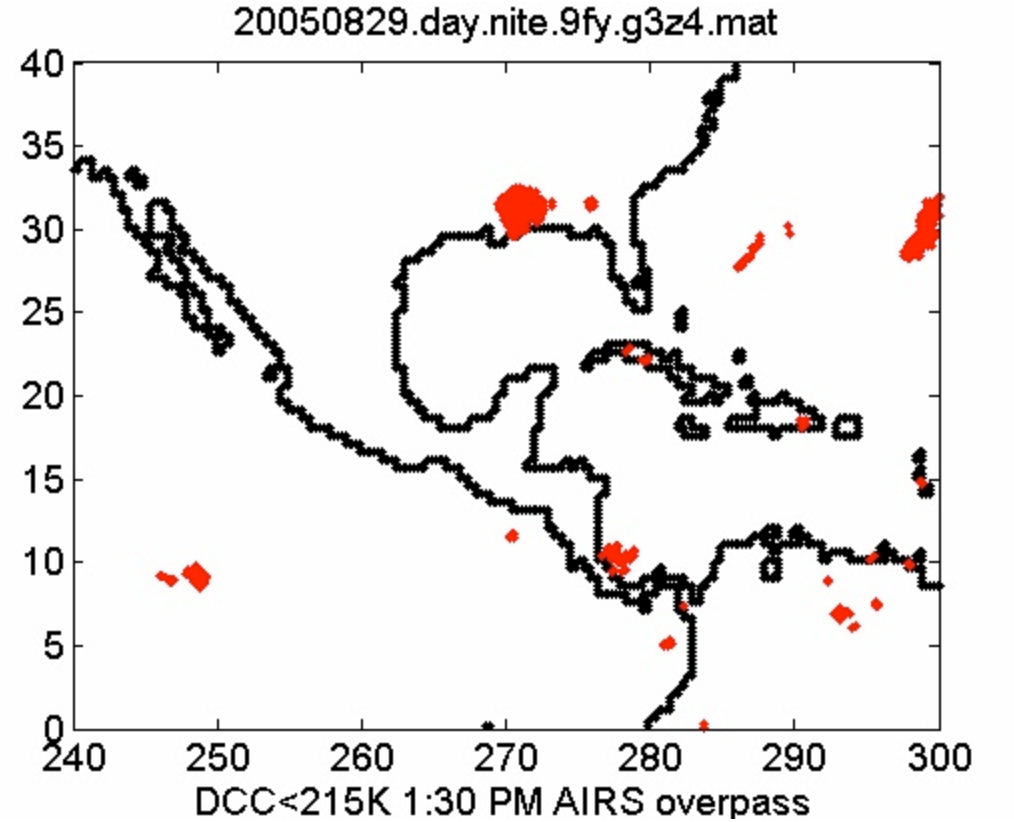
www.jpl.nasa.gov/airs

Most DCC are found in clusters with more than 50 DCC in a 2 x 2 degree box



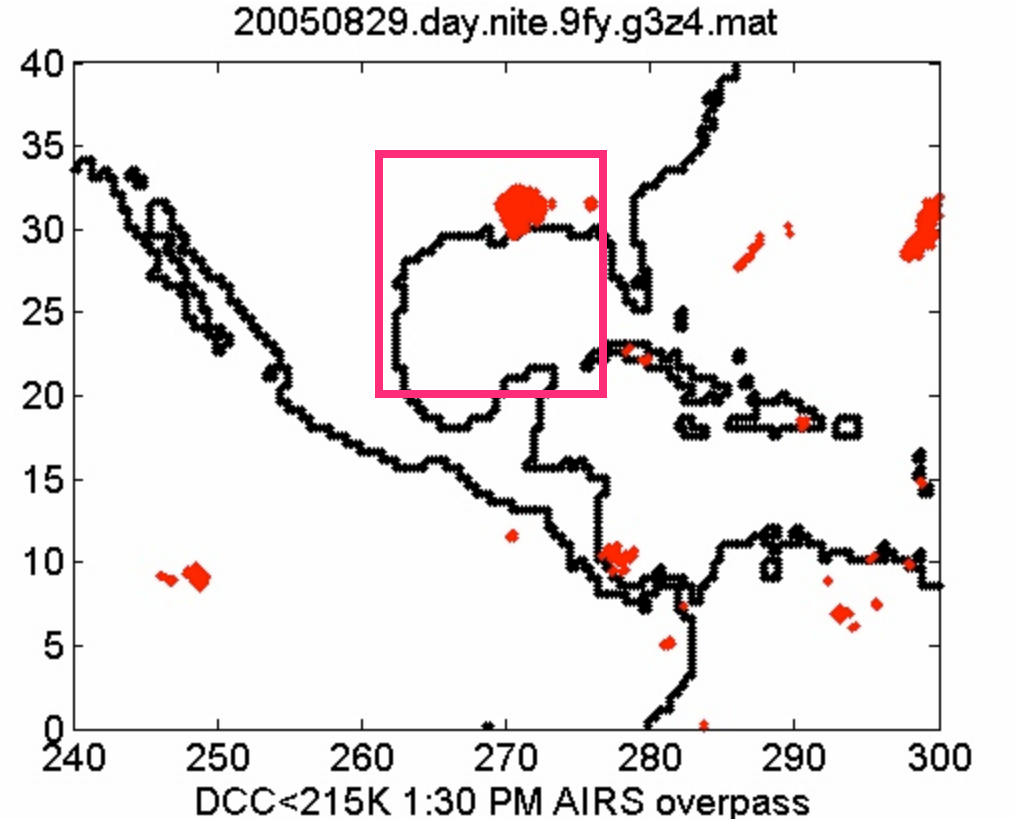
DCC on 20050819 during the 1:30 AM orbits.

Hurricanes Katrina at the overpass of New Orleans 2005/08/29 contained 241 DCC and was rated category 2



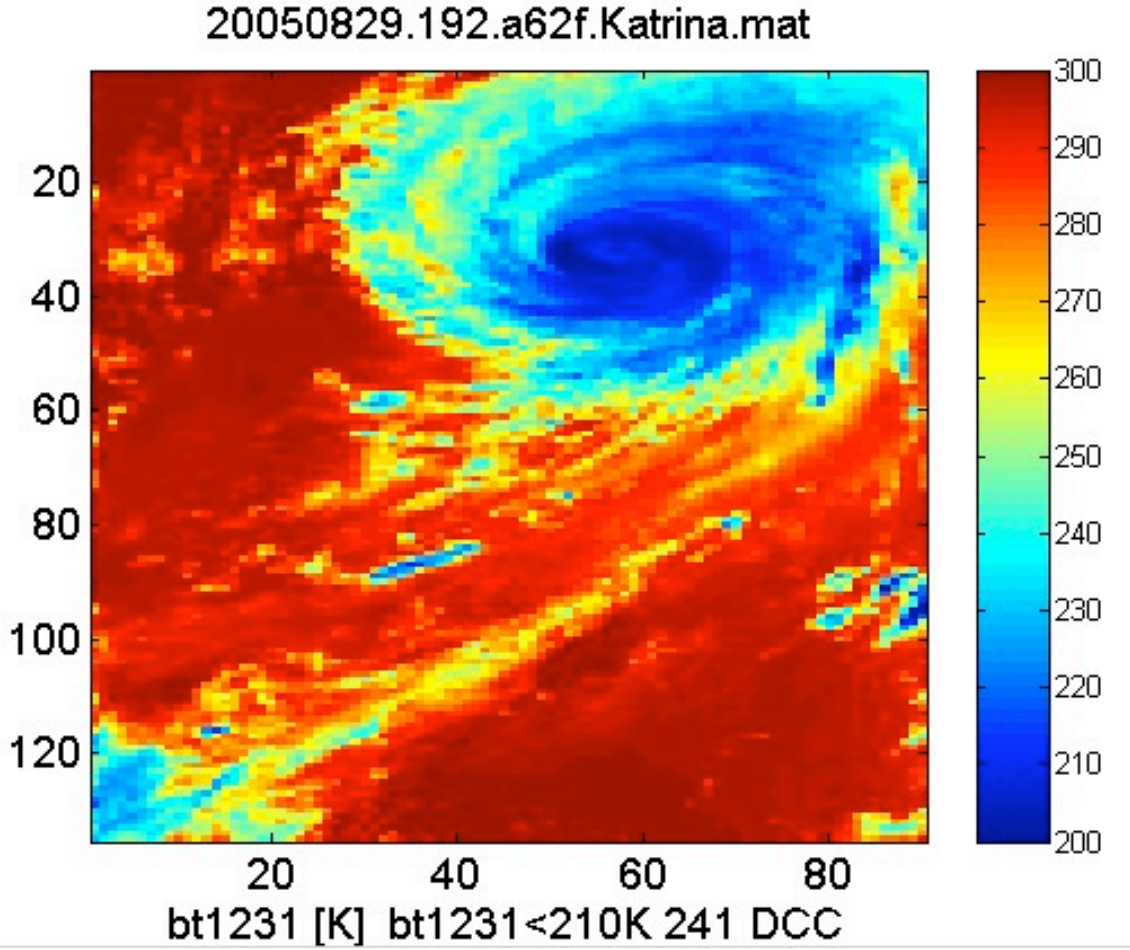
cyan=1:30 AM red=1:30 pm overpass

We zoom in on an AIRS data granule to see what Katrina looks like at 1231 cm-1



cyan=1:30 AM red=1:30 pm overpass

Hurricane Katrina shortly after crossing into land contained 241 DCC



cyan=1:30 AM red=1:30 pm overpass

Hurricanes Katrina overpass of New Orleans 2005/08/29